5/Priority Doc.
E. Wilkins
4-5-01

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I also certify that by virtue of an assignment registered under the Patents Act 1977, the application is now proceeding in the name as substituted.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

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Signed M Cooke

Dated 5 December 2000

GB9928074.5

By virtue of a direction given under Section 30 of the Patents Act 1977, the application is proceeding in the name of

MARCONI APPLIED TECHNOLOGIES LIMITED
Incorporated in the United Kingdom
One Bruton Street
London
W1X 8AQ
United Kingdom

[ADP No. 07803513001]

Patents Form 1

Patents Act 1977
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29NOV99 E4[redacted]194-1 000314
P01/7700 0.00-9928074.5

Request for grant of a patent

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The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1. Your reference **P/62190.GBA/VMIC**

2. Patent application number *(The Patent Office will fill in this part)* **9928074.5** 29 NOV 1999

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*
Patents ADP number *(if you know it)* 39873850 02

EEV Limited
Waterhouse Lane
Chelmsford
Essex
CM1 2QU
United Kingdom

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention
Switching Arrangement

5. Name of your agent *(if you have one)* **G. Cockayne**

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* **GEC Patent Department, Waterhouse Lane, Chelmsford, Essex CM1 2QX**

Patents ADP number *(if you know it)*
1009133003

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body
See note (d)

YES

Patents Form 1/77

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Description 7/

Claim(s) 2 /2ML

Abstract 0 /

Drawings(s) 2

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Priority documents (-)

Translations of priority documents (-)

Statement of inventorship and right to grant of a patent *(Patents Form 7/77)* (-)

Request for preliminary examination and search *(Patents Form 9/77)* (-)

Request for substantive examination *(Patents Form 10/77)* (-)

Any other documents (-) *(please specify)*

11. I/We request the grant of a patent on the basis of this application.

Signature Date **29 November 1999**

12. Name and daytime telephone number of person to contact in the United Kingdom **G. Cockayne - Telephone No. 01245 275459**

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After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

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7/77

104

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Statement of inventorship and of right to grant of a patent

1. Your reference
   P/62190.GBA/VMIC

2. Patent application number
   (if you know it) **GB 9928074.5**

3. Full name of the or of each applicant
   Marconi Applied Technologies Limited

4. Title of the invention
   SWITCHING ARRANGEMENT

5. State how the applicant*(s)* derived the right from the inventor*(s)* to be granted a patent
   By virtue of Section 39(1) of the 1977 Patents Act and by assignment

6. How many, if any, additional Patents Forms 7/77 are attached to this form?
   (see note (c)) *NONE*

7. I/We believe that the person*(s)* named over the page *(and on any extra copies of this form)* is/are the inventor*(s)* of the invention which the above patent application relates to.

   Signature [signature] Date **9 June 2000**

8. Name and daytime telephone number of person to contact in the United Kingdom **Gillian Cockayne (01245 275459)**

Notes

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18946 JSA4

Patents Form 7/77

Enter the full names, addresses and postcodes of the inventors in the boxes and underline the surnames

Robert RICHARDSON
42 King Edward Road
South Woodham Ferrers
Chelmsford
Essex
CM3 5PQ

Patents ADP number *(if you know it)* 32755e700

Patents ADP number *(if you know it)*

Patents ADP number *(if you know it)*

Reminder

Have you signed the form?

DUPLICATE

Switching Arrangement

This invention relates to a switching arrangement and more particularly to a switching arrangement involving solid state switches.

It has previously proposed to connect together a plurality of solid state switches, in series or in parallel, to enable a high voltage output pulse to be obtained. Each solid state switch is included in a module carrying circuitry for the application of trigger (or control) signals to the switch and also for the provision of an LT power supply. Several tens of such modules may be stacked together to provide the required high voltage output.

The present invention arose from the consideration of in what way triggering signals may be applied to solid state switches where a large number of switching modules are involved. However, the invention is also applicable to switching arrangements having less onerous voltage isolation requirements.

According to the invention, there is provided a switching arrangement comprising a plurality of modules, to each of which energy and/or trigger signals are to be applied, each module carrying two current transformer secondary windings and there being a primary transformer loop in the form of a transmission line which is common to each module and which couples with the two transformer windings of each module.

In a preferred embodiment, the arrangement provides combined triggering and local LT via a single current path, that is, via the transmission line, but the invention may be also usefully applied where only one of these signals is to be applied to the module via the

transmission line.

The transmission line ideally is matched but it is possible that useful operation may still be achieved where there is a slight mismatch.

A discussion of use of a transmission line to transmit a signal may be found at pages 86 - 90 of "Pulse, Digital, and Switching Waveforms" by Millman and Taub, McGraw-Hill 1965. By using a transmission line to allow the energy and trigger signals to be applied to the modules, the inductance in the circuit manifests itself as a fixed and small delay. This contrasts with previous suggested arrangements in which power is supplied to modules via a primary transformer winding consisting of a simple inductive loop, which arrangement exhibits a significant, current rise time limiting inductance. By the using the invention, a delay over a transmission line length of, say, 1 metre should be less than 4 nanoseconds or so.

Another advantage arising from the invention is that common mode displacement currents partially cancel at the two transformer windings on each module, thus reducing the risk of these currents interfering with a trigger signal and possibly causing false triggering.

The invention is particularly applicable to switching arrangements having a large number of stacked modules, in the region of 60 or more, where high voltage isolation is required. However, it may also be used for smaller stacks.

In one preferred embodiment, the two current transformer secondary windings on a module have an equal number of turns of opposite sense and are connected in parallel. In an

alternative arrangement, two windings of half value in series may be used.

Advantageously, the transmission line includes a load resistor. This enables the characteristic impedance to be matched to prevent ringing and other undesirable effects which could lead to signal distortion. In a preferred arrangement, the load resistance is located at substantially the mid-point of the transmission line. However, it has been found that alternatively, the load resistor may be placed near an end of the transmission line as still be effective. Advantageously, a by-pass diode is connected in parallel with the load resistor.

In one embodiment of the invention, means are included for transmitting a current from one source along the transmission line to provide power for local low tension on each module and from another source along the transmission line to apply triggering pulses to the modules. The current applied from one source may be in the opposite direction along the transmission line to that applied from the other source. This arrangement is advantageous as it permits each current source to be tailored for its intended use.

In a particularly advantageous embodiment, electrostatic shielding is provided around part of the length of the transmission line. This may take the form of a cylindrical conductor or mesh around the transmission line, preventing damage to elements of the circuit located in the vicinity of the transmission line. Preferably, the electrostatic shielding includes a break at substantially the mid-point of the transmission line. A resistive load or loads may be connected to the electrostatic shielding and thus any displacement currents are diverted into the resistive loads. By ensuring that these resistors match the characteristic impedance of the structure formed by the electrostatic screen and the transmission line, any current will be

dissipated during the switching edges without further ringing. Where the electrostatic shielding includes a break, a separate resistor may be connected to each part of the shielding, or alternatively a common resistor attached to both in parallel may be employed.

One way in which the invention may be performed is now described by way of example with reference to the accompanying drawings in which:

Figure 1 is a schematic block diagram of an apparatus employing a switching arrangement in accordance with the invention;

Figure 2 is a schematic circuit diagram of a switching arrangement in accordance with the invention; and

Figure 3 is an explanatory diagram relating to the operation of the circuit shown in Figure 2.

With reference to Figure 1, an apparatus for applying pulses to a load 1 utilises a switching arrangement 2 comprising a plurality of solid state switches, each switch being included in a module and the modules being assembled in a stacked arrangement. The switching arrangement 2 is connected to a power supply 3 and a reservoir capacitor 4 is connected across the switching arrangement 2 and load 1.

With reference to Figure 2, each solid state switch of the arrangement 2 is carried by an associated module, two of which 5 and 6 are shown, these solid state switches being

represented as blocks at 7 and 8. In this particular arrangement, the stack comprises 60 or more nominally identical modules, and the switches 7 and 8 are power FETs.

With reference to module 5, a triggering signal is applied on a line 9 to the switch 7 to control its on/off state and in addition, there is an LT supply 10 also applied to the switch 7. The module includes two secondary windings 11 and 12 of a current transformer which are wound in opposite directions and connected by lines 13 and 14 from which connections are made via 15 and 16 in a split bridge configuration to the triggering line 9 and LT and earth connections 10 and 17.

The primary loop of the current transformer consists of a coaxial transmission line 18 which is arranged to couple with the secondary windings 11 and 12 carried by each of the modules. The transmission line 18 passes through one of each pair of secondary windings carried by each module in turn along the stack and then returns to couple with the remaining winding of each pair carried by each of the modules.

At approximately the mid-point of the transmission line 18, a resistor R1 is included to ensure matching of the transmission line to prevent reflections along it which could degrade performance of the arrangement. The resistor R1 is connected in parallel with a diode D1.

The arrangement includes four FETs S1, S2, S3 and S4. These are arranged such that when S1 and S4 are closed there is a connection from one rail Edc1 19 via the transmission line 18 to ground at 20. In an alternative switching configuration, the switches S3 and S2 are

closed to provide a path via the transmission line 18 from a second voltage rail Edc2 21 to ground at 20.

With reference to Figure 3, this illustrates the sequence of operation of the switches S1 to S4 to obtain the required voltage on the LT lines 10 of the modules and the generation of a trigger pulse to be applied via line 9 to the switch 7.

To obtain the LT supply, switches S1 and S4 are simultaneously energised as shown at time a_1 and then during at time a_2 switch S1 is turned off.

For production of the LT supply pulse, as resistor R1 is by-passed by diode D1, this permits voltage Edc1 at 19 to be significantly lower than voltage Edc2 on rail 21. The pulse shape degrades but this is not significant as energy is only required to be delivered by the pulses to the modules' LT circuitry. A resistor R2 connected between switch S4 and the ground rail 20 acts as a current source limit such that current through the loop is controlled to a desired value.

To obtain a trigger pulse, at time b_1, switches S3 and S2 are simultaneously energised whilst S1 and S4 are off.

When trigger pulses are not required, the negative pulses are pulsed on continuously to maintain the required voltage at the module LT rails. The pulsing rate is determined by permitting region Vta to be equal to Vtb, thus ensuring the transformer fully resets. The backswing voltage permitted Eb may be arranged to be significantly less than Edc2. This

thus provides an adequate noise immunity margin. The LT pulses are conveniently of a similar width to the main drive pulses applied to the load. However, if the mean current demands require it, it may be at a higher PRF say 3000 to 10000 pps. The required trigger drive pulses b1 to b2 may be produced at any time, including interrupting the LT cycle pulses. To enable this to be achieved, the transformers should have a flux capability of twice the VT product required for a single pulse.

In this embodiment, all of the switches S1 to S4 are FETs and optical bootstrap style drives are used for switches S1 and S3. Edc2 is about 800 volts and Edc1 is about 100 volts.

Shielding 22 is provided around the transmission line, being interrupted at its mid-point and each half of the shielding 22 being connected to a resistor R3 and R4, which may be common to both parts of the shielding 22. The electrostatic screen 22 fitted over the primary loop 18, with a break at the D1, R1 junction at its mid-point to ensure that any displacement currents are diverted into resistors R3 and R4. Resistors R3 and R4 are arranged to match the characteristic impedance of the structure formed by the screen 22 and the inner loop 18 such that any current is dissipated during the switching edges of the pulses without further ringing.

The invention may be applicable to, for example, medical linac applications. For such applications, the average power required is low. Thus, it may only be necessary to control the negative pulses to top up the module LT rails to pulse at the normal operating PRF of the main pulses applied to the load.

Claims

1. A switching arrangement comprising a plurality of modules, to each of which energy and/or trigger signals are to be applied, each module carrying two current transformer secondary windings and there being a primary transformer loop in the form of a transmission line which is common to each module and which couples with the two transformer windings of each module.

2. An arrangement as claimed in claim 1 wherein the primary transformer loop comprises a coaxial line.

3. An arrangement as claimed in claim 1 or 2 wherein the two current transformer secondary windings on a module are an equal number of opposite turns and are connected in parallel.

4. An arrangement as claimed in claim 1, 2 or 3 wherein each module is associated with a solid state switch to which trigger signals are applied via the transmission line.

5. An arrangement as claimed in claim 4 wherein the solid state switches are connected to provide a voltage output of some tens of kilovolts.

6. An arrangement as claimed in any preceding claim wherein the transmission line includes a load resistor.

7. An arrangement as claimed in claim 6 wherein the load resistor is located at substantially

the mid-point of the transmission line.

8. An arrangement as claimed in claim 6 or 7 wherein a by-pass diode is connected in parallel with the load resistor.

9. An arrangement as claimed in any preceding claim and including means for transmitting a current from one source along the transmission line to provide power for local low tension on each module and from another source along the transmission line to apply triggering pulses to the modules.

10. An arrangement as claimed in claim 9 wherein the current applied from one source is in the opposite direction along the transmission line to that applied from the other source.

11. An arrangement as claimed in any preceding claim and including electrostatic shielding around part of the length of the transmission line.

12. An arrangement as claimed in claim 11 wherein there is a break in the electrostatic shielding at substantially the mid-point of the transmission line.

13. An arrangement as claimed in claim 11 or 12 and including a resistive load connected to the electrostatic shielding.

14. An arrangement substantially as illustrated in and described with reference to the accompanying drawings.

1/2

Fig. 1

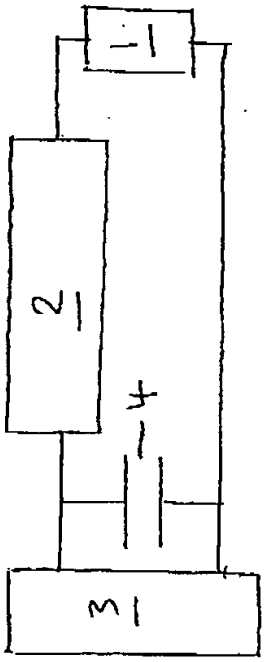
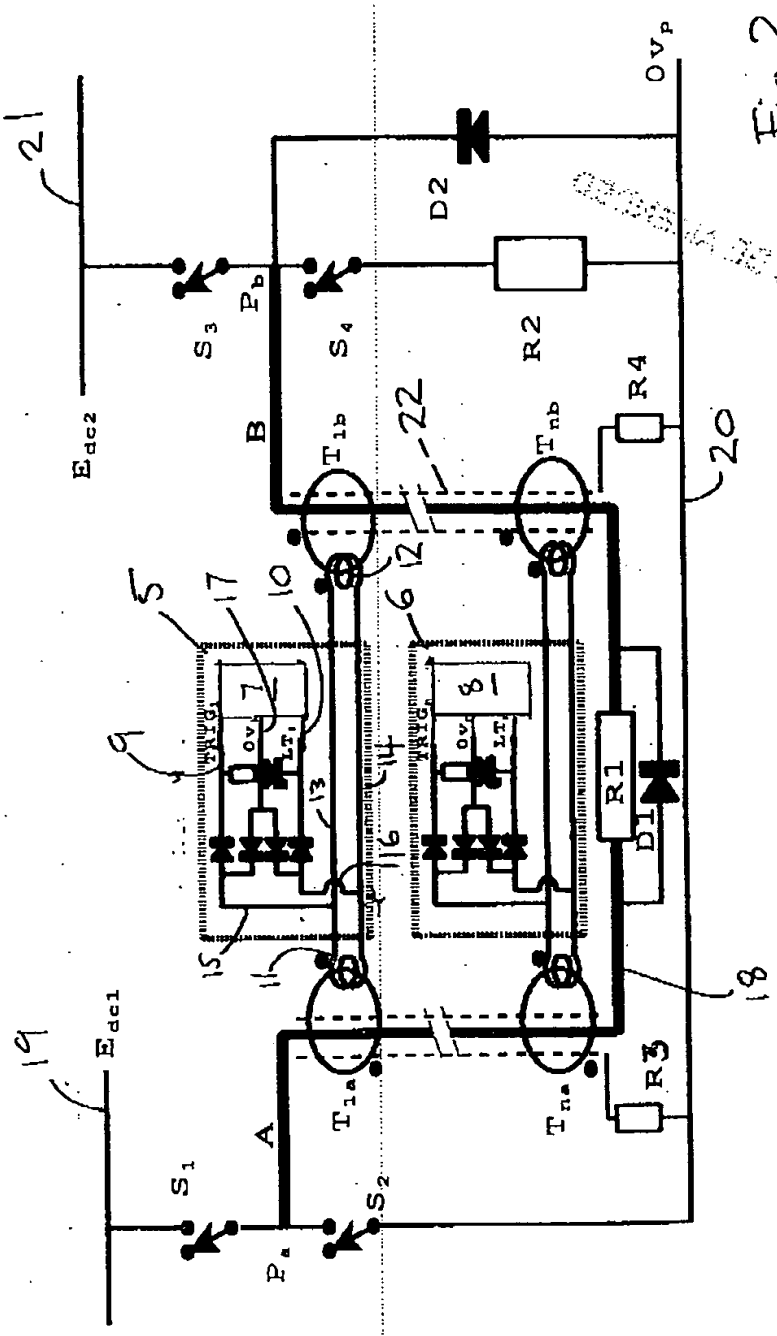

1
2
3
4

Fig. 2


21
E_{dc2}
S_3
P_b
S_4
D2
Ov_P
R2
R4
B
T_{1b}
T_{nb}
22
20
12
5
17
10
6
7
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9
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LT_1
LT_n
13
14
16
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11
R1
D1
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A
T_{1a}
T_{na}
R3
S_1
S_2
P_a

2/2

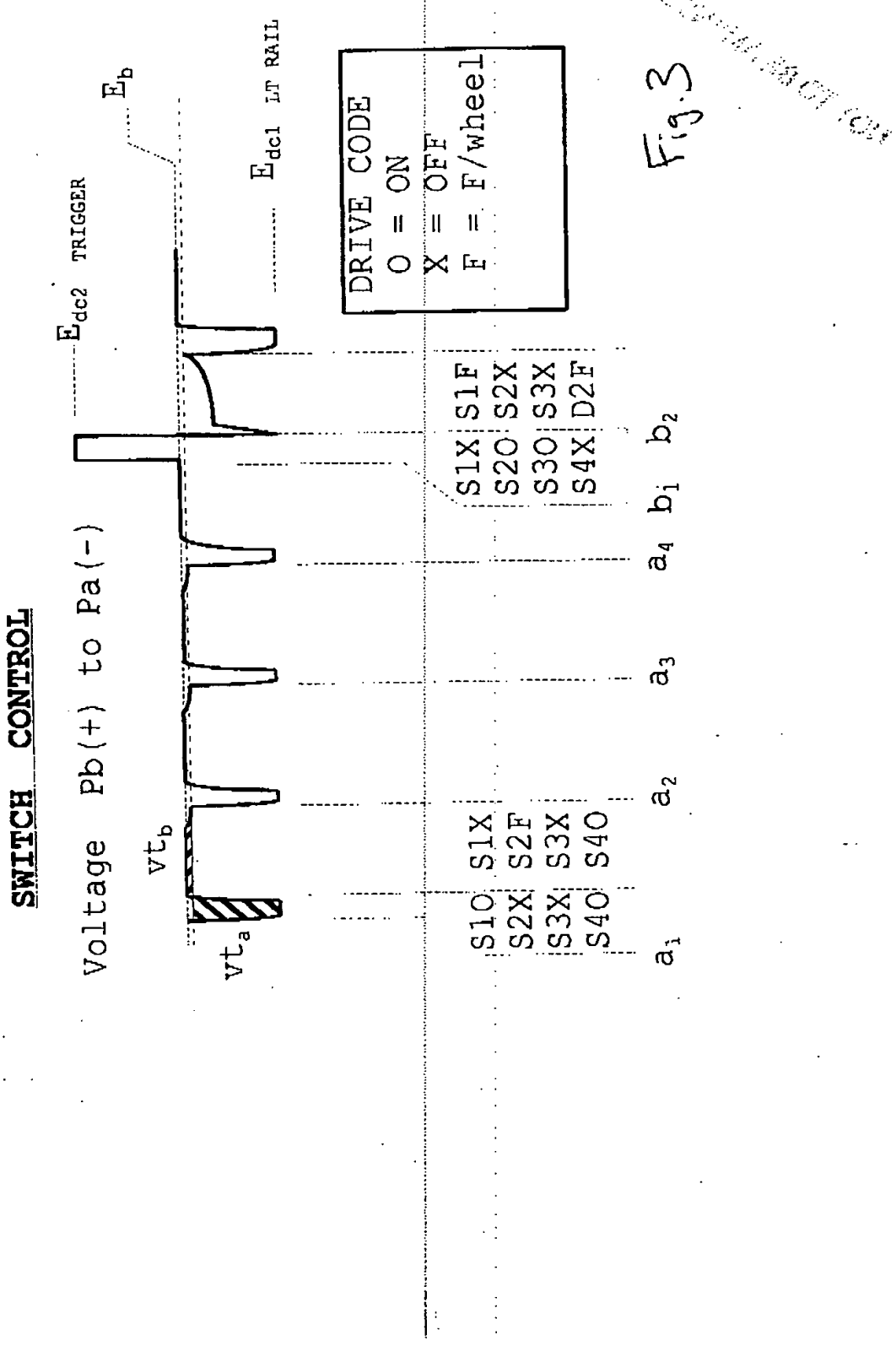
SWITCH CONTROL
Voltage Pb(+) to Pa(-)
E_{dc2} TRIGGER
E_b
E_{dc1} LT RAIL
vt_b
vt_a
DRIVE CODE
O = ON
X = OFF
F = F/wheel
S1X S1F S2X S3X D2F
S1X S2O S3O S4X
S1O S1X S2F S3X S4O
S2X S3X S4O
b_2
b_1
a_4
a_3
a_2
a_1

Fig.3